Laboratory Set-up for the Analysis of Motorcyclists' Behaviour During Deceleration

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Abstract: Despite the improvements in the field of safety, every year there are more than 6,000 powered two-wheeler fatalities in Europe. Within the context of the European Project MYMOSA (MotorcYcle and MOtorcyclist SAfety), this study aims to support the development of computational models for motorcyclists. For this purpose, experiments with volunteers were made to obtain information about body posture and reactions of the motorcyclists during deceleration. Human motion capture and electromyography were applied to record the biomechanical outputs.

A mechanical sled with a construction that reproduced the geometry of a motorcycle was used for the experiments. The sled was moving with acceleration values up to 0.5g. The front part of the construction was placed backward to the 3m long travel direction of the sled. So the initial acceleration of the volunteers was backward like on a decelerating motorcycle.

For some experiments the onset was unexpected for the volunteers. They were wearing earphones with music and a black fabric was used to cover the construction's front field. The set-up was found to be appropriate for the investigation of differences between active and passive stabilization during deceleration.

Keywords: motorcycle; neck; motion analysis; electromyography

1 Introduction

Every year, road traffic related accidents claim an estimated 40,000 lives and injure 1,600,000 citizens in Europe [1]. Motorcyclists' casualties are estimated somewhere between 1/6 and 1/8 of total road fatalities [2] and it is clear that the corresponding research effort and budget are not allocated in proportion with the relevance of motorcycles within the road safety context. Existing motorcycle-related experimental trials are very limited in number and generally very specific in goals [3]. This study aims at filling some of that gap, launching a roadmap of real-world trials alongside the much-needed development of computational models for motorcyclists. Because motorcyclists' posture and movement significantly influence the global system's behaviour (motorcycle+rider), experiments with volunteers are necessary to study body posture and reactions during riding, therefore improving and validating computational models. Human movement analysis techniques and ElectroMyoGraphy were applied to generate record and process a number of biomechanical indicators and extract numerical data and qualitative insights.

2 Materials and Methods

2.1 Positioning devices and Sled

A short study on the motorcycle geometry was performed. A sample of 30 different motorcycle models was analyzed using side view digital photographs and a method based in photogrammetry. The motorcycle models were all the models available in the German market from a single manufacturer. The motorcycles were grouped according to their style in different categories. The selection of the categories was according to the MAIDS report [4]. The selected geometrical characteristics, important for this study were the handlebar, the footrests and the seating point on the saddle.

The pixel coordinates of the points where the wheels touch the ground, the handlebar, the footrests and the seating point were found manually on each photograph. These points were then rotated so the motorcycles were horizontally. Usually, the motorcycle manufacturers provide the saddle height for each of their model. So this value was selected as a reference to transform the pixel coordinates to real world length measurements. The geometry of one motorcycle was also measured using the motion capture system described below and the accuracy of the photogrammetric method used was found to be around 2cm.

The motorcycle geometries present a big variability but the restrictions of time and volunteer's availability for the experiment, forced the selection of only one, single geometry. The geometry selected is representative of most big motorcycles but not of cruiser and scooter.

Table 1 Horizontal and Vertical distances of the selected points from the seating point, for various motorcycle styles.

Style	#Samples	H_s_handle	V_s_handle	H_s_foot	V_s_foot
conventional	2	29	24	0	-48
sport	6	26	10	-1	-47
cruiser	4	18	28	20	-44
touring	2	20	25	6	-51
scooter	5	24	22	20	-48
sport_touring	7	28	27	3	-51
enduro	2	21	20	2	-54
MGD		25	26	2	-54

A Device was built that could reproduce the Geometry of a Motorcycle (MGD). The MGD included only the motorcycle - rider interface. Adjustable handlebar, footrests and fuel - tank positions, allowed variability in geometries of motorcycle styles. The MGD was mounted on a sled; a construction with a falling weight was used to accelerate the sled. The acceleration pulses of the sled could vary from 0 to 0.7g for a travel distance of 3m. The sled motion was initiated with the release of a lever after the deactivation of an electromagnetic clamp. The MGD was instrumented with a brake at the right handle, which at the middle of its lever movement was activating an electrical signal, recorded with a data acquisition device at a sampling rate of 1000Hz. The sled could be activated externally from the MGD-volunteer system, by a researcher or internally by the braking action of the volunteer.

The deceleration that emerges from motorcycle braking at a certain traveling speed was simulated with backward motion of the MGD with a constant acceleration. The acceleration was measured with a uni-axial accelerometer. Restraint systems and protective foams were used to protect the volunteers from a falling accident or in case of unexpected reactions.

2.2 Measuring Devices and Volunteer Instrumentation

An optical motion analysis system was used to capture the motion of the volunteer. Reflective markers were placed on several anatomical landmarks of the volunteer's body. Especially for the head and neck, markers were placed on the prominent process of the seventh cervical vertebrae, on the occipital protuberance, on the sternum, and on the tragus of each ear. The motion of the markers was recorded with eight high speed cameras with red light strobes. Their frame rate was set to 1000Hz. Their position permitted each marker to be visible from at least two of them during the performance of each experiment. A surface EMG device with eight channels was used to measure the muscle activity of three neck (splenius capitis, sternocleidomastoid and posterior cervical muscles) and one arm (lateral head of triceps brachii) muscles, with the reference electrode placed on the mastoid process. The neck surface electrodes where placed according to [5,6]. All signals where synchronized and recorded with a computer in ASCII format.

A motorcycle helmet was not used because it would cover relevant anatomical points on the head. A bicycle helmet was used instead with additional weight mounted perimetrically to represent the additional inertial mass on the head from wearing a motorcycle helmet. The total weight was 1kg for the male volunteers and 0.8kg for the female volunteers.

Anthropometric measurements were performed on each of the volunteers. Their height, weight and neck circumference were measured according to [7].

A neutral head position was selected with a horizontal Frankfurt plane of the volunteer's head. This plane is defined by the lower point of the left orbit and upper point of each tragus. To make the volunteers maintain the same head position at the beginning of every repetition of the experiment and to try to keep them focused on a certain point, like the horizon or the road in actual riding conditions, a special technique was used. The volunteers were asked to look forward while riding the MGD. They wore a pair of glasses with a marked horizontal line in the middle of the glasses from side to side. Subsequently, the volunteer was instructed by the researchers to flex or extend his neck so that the head was positioned with a horizontal Frankfurt plane. Finally, a thread was placed at a horizontal distance of 30cm from the handlebar, in front of the volunteer and at a height where he could align the line of the thread with the horizontal line on his glasses, without moving his head from the neutral position. The relative vertical movement between the eyes and the head was eliminated with this method as well.

The volunteer was wearing earphones with loud music to prevent him from detecting the initiation of motion of the sled. A black fabric was used to cover the front field of view of the volunteer, thus keeping him from visually perceiving the onset of the experiment.

Figure 1 Volunteer with instrumentation riding the MGD

2.3 Protocol of the Experiment

The protocol was approved by the ethics committee of the University of Munich. The volunteers where interviewed concerning their medical history and any neck problems before the experiment. Their riding experience was also recorded. Right before the experiment, the volunteers were informed about the risks and asked to sign a consensus for the participation in the experiment.

Eight volunteers, five males and three females with no medical history of neck disorders participated in the experiment. Their average age was 29 years. Four of them had motorcycle riding experience.

Two different sled accelerations were employed: 0.2g and 0.4g. For the higher acceleration two different methods were used to initiate the sled, one internal and one external, therefore simulating the alert and surprised reaction of the volunteer in different braking scenarios. Each experiment was performed with two repetitions. After the completion of all the measurements for each volunteer, three Maximum Voluntary Contractions of head flexion and extension were performed. A total of 48 experiments were accomplished.

3 Results and Conclusions

A protocol for the measurement of head-neck kinematics and cervical muscle activity of motorcyclists during braking was successfully executed. Motion and neck muscle EMG activity and sled acceleration was recorded for eight volunteers during repeatable constant sled decelerations. The further analysis of the results will generate relevant time histories and behavioural insights which shall provide validation and further development of a biofidelic active head-neck computational model.

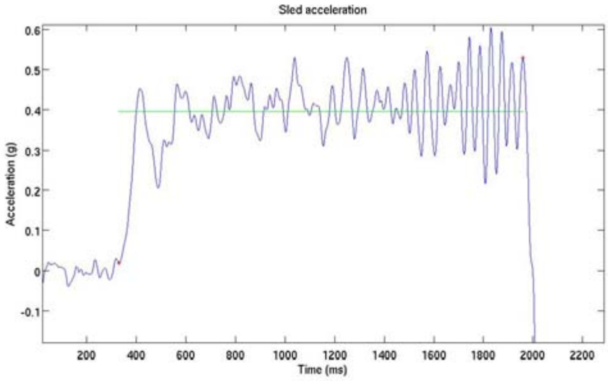

Figure 2 Sled acceleration filtered with CFC-60 type filter (blue line) and average sled acceleration (green line)

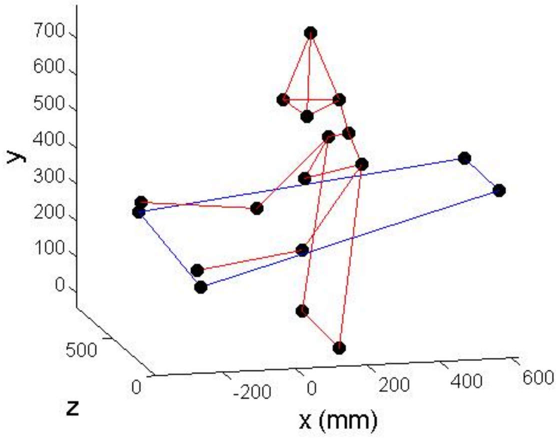

Figure 3 3D reconstructions of the marker points

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